Gypsy Moth News

October 1993

Issue No. 33

Gypsy Moth,
an agent of:

damage OR **change**

?

See articles on pages 4 and 8.

PLUS

- gypsy moths travel by ship to North Carolina.
- egg mass surveys - how to do it.
- Arkansas.

United States
Department of
Agriculture

NORTHEASTERN AREA
State and Private Forestry

Contents

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From the Editor

John Quimby, a forest entomologist with the Pennsylvania Bureau of Forestry writes in an article in this issue, "The impact of gypsy moth caused tree mortality depends upon one's perspective". What perspectives are there?

- You could own 25 acres of oak forest and hope to sell some of it for timber in a few years.

- You could own a sawmill and hope to benefit from alot of available timber to cut at good prices.

- You could work for a State forest and have an interest (but not a financial one) in woodland management.

- You could have nothing whatsoever to do with forests except to see them as you drive by.

I could go on for quite a while. The point is, the impact of tree mortality, even the use of the word "impact" to describe gypsy moth effects, depends upon where one sits. Dave Gansner in his "What's Up with Billy Penn's Oaks?" describes the effect gypsy moth has had upon the Pennsylvania forest resource--and his description is from a distance. That is, when viewed from above or from a State or regional perspective, the effect of gypsy moth defoliation over a 20-year period appears to have been largely as an agent of change and not necessarily a bad change at that. Quimby points out that if you happened to have owned a prime piece of this change, you might feel differently about the little moth. I'm sure any landowner who has battled to save a forest would feel that talk of change comes easy when you work for the government. And, not so easy to accept when you're the one who pays for that change.

Nevertheless, the Ganser and Quimby articles presented in this issue represent must reading for anyone interested in gypsy moth management. For too long, the phrase "gypsy moth impact" has been used almost without thinking. Read these articles and answer for yourself: Is the gypsy moth an agent of destruction or an agent of change?

-DBT

LETTERS TO THE EDITOR

B. M. from Pennsylvania asks:

> **"What is Forest Service's definition of infestation? I ask because with reference to Asian Gypsy Moth, only adults were found; no evidence of a breeding population. My understanding is that infestation means a breeding population. Also, if there were no breeding populations, can USDA validly claim there was eradication if there were no breeding populations to begin with?**

Dan Twardus responds:

As your question implies, an insect infestation is considered to be a population that is reproducing or capable of reproducing. With respect to the Asian Gypsy Moth eradication project that took place in the Northwest in 1992, a Science Panel was convened to review information and make recommendations to the USDA and the Oregon and Washington State Departments of Agriculture. According to Dr. William Wallner, a Forest Service scientist and member of that Panel, the Panel decided that a high probability of reproducing populations existed. And further, an Asian gypsy moth population was assumed to have survived from egg hatch to adult somewhere besides on board ships, and 2) the Northwest climate is suitable for the survival of Asian gypsy moths. Dr. Vic Mastro, Director of the Animal Plant and Health Inspection Service, Methods Development Center, and also a member of the Science Panel, adds that evidence existed of reproducing North American gypsy moths within the area of concern. Dr. Mastro has commented that the Panel was very concerned about the chance of hybridization between North American and Asian gypsy moths. Since the Asian gypsy moth female is a strong flier, any delay in acting may have resulted in a considerably larger area of eradication. The Panel could have recommended that an intensive monitoring system be put into place in order to find additional life stages. According to Dr. Wallner, the Panel felt this would have added unnecessary delay given the extent of moth trap catch, the pattern of moth catch, and the existence of reproducing North American gypsy moths. J. Bell, Agriculture Canada, adds that "preventing the establishment" of the insect in the Northwest has been the goal of eradication.

G.B. from Massachusetts asks:

> **"USDA, APHIS has a production facility in Niles, MI for mass rearing beneficials. They have not been involved with gypsy moth, but now that Michigan is clearly at or near the leading edge, why not explore the possibility of APHIS involvement of augmentative releases of beneficials like *Calosoma sycophanta* that has not spread as fast as the pest? (Rearing technique exists already.)"**

Dale Meyerdirk, Biological Control Specialist, APHIS, PPQ, responds:

The United States Department of Agriculture (USDA) has initiated the development of a workshop to address the implementation of biological control against the gypsy moth. USDA will capitalize on the workshop's findings and focus on specific natural enemies recommended for release and the geographical regions to be targeted for the release program. The Animal and Plant Health Inspection Service (APHIS) is presently assisting with the commercialization of a gypsy moth virus for control purposes, and developing rearing techniques for the mass production of an exotic parasitic fly recently introduced into the United States. The mass production and release of the predaceous beetle, *Calosoma sycophanta*, will be addressed by the future workshop and recommendations will be forthcoming.

L. L. from Idaho writes:

> **"What is the status of the testing conducted to determine the suitability of western plants for the Asian strain of gm?"**

Dr. Michael E. Montgomery, USDA Forest Service, Hamden, CT, responds:

This past spring in the USDA Forest Service Quarantine Laboratory in Ansonia, CT, 45 plant species were assayed for

their suitability as hosts for the Asian and the European races of gypsy moth. Because of space and other limitations in the Quarantine Laboratory, and our desire to test several species in a well-replicated design, we elected to rear the newly hatched larvae for 10 days on excised foliage of each host. The establishment and growth of first instar larvae is usually the most limiting determinant of the host plant range of the gypsy moth.

The western species tested are of the intermediate suitability class. In the following table, weights after 10 days on these can be compared with black oak, a known suitable host, and green ash, an unsuitable host.

	10-day weight (mg)	
Common Name	**European**	**Asian**
Black oak	**10.6**	**27.7**
Douglas fir	**1.9**	**9.2**
Manzanita	**3.0**	**6.4**
Western larch	**3.0**	**4.8**
Western white pine	**2.6**	**4.8**
Fremont cottonwood	**1.5**	**4.9**
Green ash	**1.4**	**2.9**

Except for only 54% survival of the European race on Douglas fir, there was greater than 90% survival of both races on these species. The weight attained on western larch was less than expected and may reflect that the larvae frequently severed the tender shoots and thus had only wilted foliage available for part of the feeding period.

For the 45 plant species, the Asian race averaged twice the size of the European race. Species that were immune to the European race (i.e., larvae could not grow or survive) also were immune to the Asian race. In summary, these and other tests indicate that the Asian race of gypsy moth would be a more serious problem in western forests than the European race. More species testing will be done next spring with hybrid crosses included in those tests.

B.R. from Kent, Ohio, writes:

"I would appreciate it if you would send any information regarding the use of biological, botanical, and biorational products for managing gypsy moth and/or other distinctive pests of landscape ornamental plants."

Allan Bullard, Acting Director of the National Center of Forest Health Management, in Morgantown, WV, responds:

While few gypsy moth products have been developed specifically for landscape and ornamental use, many are registered for use in this area and a great deal of recent work has been done that has potential application to the landscape/ornamental/homeowner market.

In answer to your specific request for information, I have sent a copy of "Homeowner's Guide to Gypsy Moth Management" by Emily Grafton and Ralph Webb. The recently-completed Appalachian Integrated Pest Management (AIPM) Project extensively evaluated different formulations and dose rates of *Bacillus thuringiensis* (*Bt*) and the gypsy moth nucleopolyhedrosis virus product GYPCHEK for use against gypsy moth as well as evaluating pheromone flakes and beads for use in mating disruption. I have also sent copies of several publications dealing specifically with these studies as well as a copy of the bibliography of publications of the AIPM Project. In addition to these articles, publications describing the fungus *Entomophaga maimaiga* and mating disruption are in preparation and expected shortly. I will send copies as they become available.

WHAT'S UP WITH BILLY PENN'S OAK?

By David A. Gansner, Stanford L. Arner, Richard H Widmann, and Carol L. Alerich

It is no secret that Pennsylvania's oak timber has suffered during the past couple of decades. Gypsy moth defoliation, drought, cutting, deer browsing, and other stresses have strained the resource. To see stark evidence of how bad tree mortality has been in some parts of the state, take a ride on the Pennsylvania turnpike and check out the landscape in Bedford and Somerset Counties. Resource managers, the wood-using industry, and a host of others are seriously concerned and want to know more about the severity and extent of this problem.

Table 1. Mortality and cutting, by species group, Pennsylvania 1978-1989.

Species	Cumulative mortality and cut 1978-1989 cubic ft./acre	Mortality and cut as percent of 1978 inventory
Chestnut oak	37	30
N.red oak	45	28
Black oak	19	33
White oak	22	27
Other oak	9	34
All oak	132	30
Other hardwoods	163	20
Softwoods	16	13
All species	311	23

Much of the decline in Pennsylvania oak occurred during the 1980's. So we're fortunate that a comprehensive re-inventory of the commonwealth's forests was completed for 1989 (Alerich, 1993). Data from more than 2000 plots remeasured in that survey allows us to review specific trends in the stocking of oak on land that has remained in forest since the last inventory of 1978.

Growth Softens Impacts of High Mortality and Cutting

Cumulative mortality and cutting for all species averaged more than 300 cubic feet per acre between 1978 and 1989 (Table 1). Much of it was in oak, amounting to 30 percent of the 1978 inventory of oak growing stock (sound trees 5.0+ inches in dbh). This combined rate of mortality and cutting for Pennsylvania was much greater than the average for central Appalachian oaks as a whole (Gansner et al. 1991). It also exceeds rates recorded for the Quaker state's softwoods (13%) and other hardwoods (20%).

Residual oak trees grew enough to offset most of the effects of cutting and mortality. So on net, there was little change in the volume of oak per acre of timberland between inventories. At the same time, however, other hardwoods such as maple, cherry, yellow-poplar, birch, ash, gum, and softwoods such as hemlock and white pine have flourished (Table 2). Thus, oaks now represent a smaller share (27%) of Pennsylvania's timber supply than they once did (33%).

Table 2. Change in growing-stock volume, by species groups, Pennsylvania 1978-1989.

Species	Saw timber volume % of inventory 1978	1989	%change from 1978
Chestnut oak	9	7	2
N.red oak	12	10	11
Black oak	4	3	-3
White oak	6	5	-2
Other oak	2	2	0
All oak	33	27	3
Other hardwood	58	63	32
Softwood	9	10	38
All species	100	100	23

Timber Bigger But Trouble in Smaller Sizes

In the wake of drought, gypsy moth, deer browsing, and other pestilence, losses usually are most noticeable in smaller, lower quality, understory trees. That trend certainly held true for Pennsylvania oaks. Oak growing-stock volume in trees less than 12 inches dbh actually decreased between inventories (Fig 1).

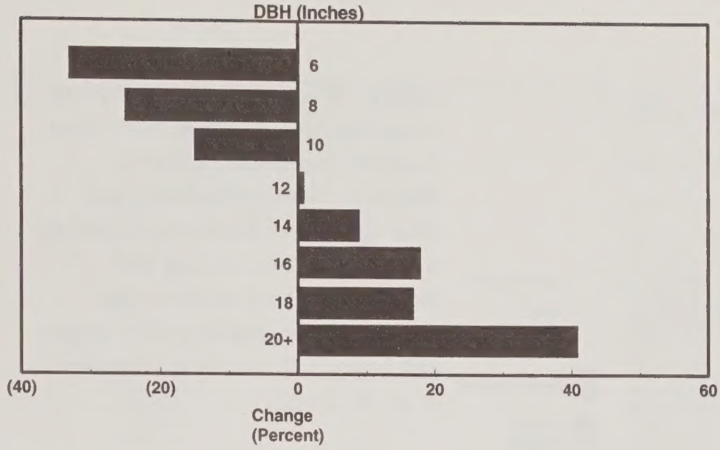

Fig. 1 Percent change in oak growing - stock volume by DBH class, Pennsylvania, 1978 - 1989.

Volume gains in larger trees made up for the loss in smaller trees. In general, the bigger the trees, the greater the percentage increase in volume. The volume of oak suitable for sawtimber increased by more than 200 board feet per acre or 19 percent between 1978 and 1989 (Table 3). Again, because increases for other species were much greater than for oak, oaks account for a smaller proportion of the sawtimber inventory than formerly.

The decline in smaller understory oaks could hold serious implications for the future. This situation is further complicated by a growing emphasis on conservative, selective cutting methods that encourage the regeneration and development of shade tolerant species such as beech and maple instead of shade intolerant oaks.

Stocking of Oak-Hickory Forest Has Improved

Even though the average amount of oak growing stock on an acre of timberland didn't change much, the stocking of oak-hickory stands improved between inventories. To get a timber manager's view of changes in stocking, we classified more than 900 remeasured oak-hickory plots into stocking classes using standards developed by Gingrich (1967). These standards account for the number, basal area, and size of trees. Only trees 5.0 inches and larger that are acceptable growing stock (trees of commercial species that are not rough or rotten) were considered.

In 1978, 5 percent of the oak-hickory plots were overstocked; that is, they were so dense that individual trees were growing slowly and natural mortality was greater than normal (Fig. 2). Another 43 percent of the plots were fully stocked and making full use of their growing space. Twenty-seven percent were under stocked; still worth managing, but so sparsely stocked that growing space was wasted. The remaining 25 percent were poorly stocked; here adequate regeneration of desirable seedlings and saplings is the timber manager's primary concern.

By 1989, overall stocking had improved. Gains outnumbered declines by almost 3 to 1. As a result, fewer plots were poorly stocked and under stocked. And about three-fifths of the total were in a fully stocked or overstocked

Table 3. Change in sawtimber volume, by species group, Pennsylvania, 1978-1989.

	Sawtimber volume		
	% of inventory		% change
Species	1978	1989	from 1978
Chestnut oak	7	6	16
N.red oak	15	13	28
Black oak	5	4	12
White oak	7	5	11
Other oak	2	2	18
All oak	36	31	19
Other hardwood	53	58	56
Softwood	11	11	49
All species	100	100	42

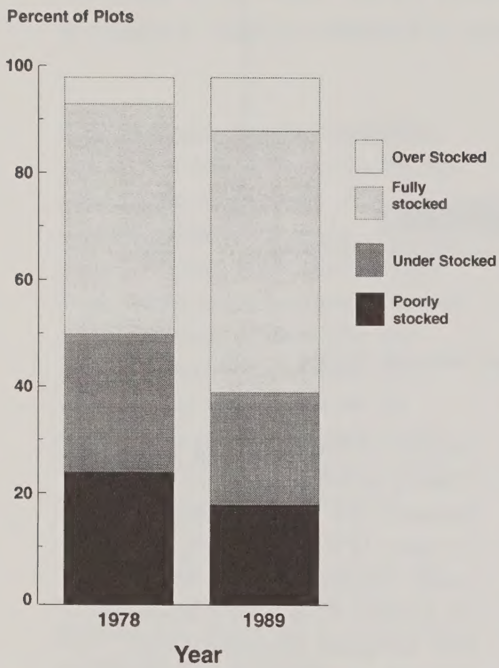

Fig. 2 Change in stocking, oak - hickory forest, Pennsylvania, 1978 -89.

condition. That means there are still plenty of opportunities for harvesting, thinning, and regeneration in Pennsylvania's oak-hickory forests.

Impacts Highly Variable

Average trends in oak stocking for Pennsylvania do not tell the whole story because mortality, cutting, and growth response were not uniformly distributed throughout the state. For example, some plots lost nearly all their volume while others flourished. Many such feast-or-famine situations can be found within shouting distance of one another.

Oaks now account for a smaller percentage of the total timber volume in virtually all parts of the state (Table 4). However, some regions fared much worse than others. Woodlands of the Pocono mountain area (Carbon, Columbia, Luzerne, Schuykill, Monroe, Montour, Northumberland, and Pike Counties) have responded to more than offset cutting and mortality and set modern-day records in the stocking of a bigger and better oak resource (Gansner et al. In press).

At the other extreme, is the Southwestern region (Bedford, Blair, Cambria, Fayette, and Somerset counties) of the state where the combined effects of mortality and cutting during the 1980's were severe. Growth counterbalanced some of the loss, but not enough to keep the per acre volume of oak from declining 17 percent between inventories. Here, many stands that were well stocked in 1978 are now in a poorly stocked condition.

Northern red oak, a favorite timber species noted for its fast growth, fared much better than the other oaks. In fact, it was the only major oak species that recorded an overall gain in volume per acre between inventories (Table 2). The volume of northern red oak suitable for sawtimber is up 28 percent (Table 3).

Oaks Remain Viable, but Future is Questionable

Most certainly, Pennsylvania's oak resource has suffered through significant amounts of mortality, cutting, and reductions in growth in recent years. Damage has been especially noticeable in the smaller size-classes. Still oak averages more than 400 cubic feet per acre of timberland and accounts for more than one-fourth of the state's total growing stock volume. Moreover, the amount of

Table 4. Mortality, cutting and change in oak growing-stock volume, by sub-unit, Pennsylvania, 1978-1989.

Subunit	Oak as % of 1978 inventory	Cut & mortality 1978-1989 as a % of 1978 inventory	Oak as % of 1989 inventory	% change in inventory 1978-1989
Pocono	48	23	43	+22
West	24	23	20	+15
Northeast	17	28	15	+10
Allegheny	14	25	13	+9
North Central	42	28	35	+4
Southeast	53	26	44	+1
South Central	58	36	48	-9
Southwest	42	44	31	-17
State	33	30	27	+3

oak suitable for sawtimber has increased to reach a new high of nearly 1400 board feet per acre (Fig. 3). Three-fifths of that sawtimber volume is in big trees; 15-plus inches DBH. And more than half the big oak volume is in butt log grade II or better trees. So, despite recent losses, Pennsylvania retains a viable oak resource.

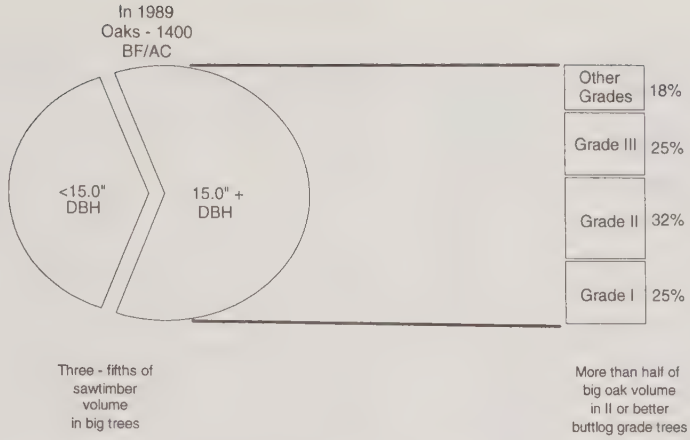

Fig. 3 Oak sawtimber volume by size and tree grade, Pennsylvania, 1989.

What about the future?

It depends on a number of interrelated complex factors, for example.

Will demands for oak significantly increase rates of cutting?

Will gypsy moth, drought, deer browsing, and other pestilence continue to plague the resource?

Will more conservative cutting practices discourage the regeneration and development of shade-intolerant oaks?

Will growth on the residual oak resource continue to offset effects of cutting, defoliation, and mortality?

Will users of oak be willing to switch to maple, strand board, plastics, and other substitutes?

Will policy makers, resource planners, and forest land managers take remedial action?

To a large extent we can control oak's destiny. Only time will tell how it all works out.

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TREE MORTALITY FOLLOWING GYPSY MOTH EPIDEMICS - 1990

By John W. Quimby

Introduction

The Pennsylvania Bureau of Forestry established 19 study areas in 1970 to track the impact of gypsy moth. One to five 1/10-acre plots were established in each of these stands. The plots were visited twice a year for the first 10 years, once to estimate defoliation, the second to count egg masses and evaluate tree vigor. In 1990, the numbers on the trees were still recognizable enough in some plots for field crews to find the surviving trees and to reconstruct the plot so ingrowth could be evaluated. Some of the plots had been cut or disturbed and so were lost. One other plot simply could not be located. In the latter case, 10 BAF variable-radius plots in or near the original plot were established to measure tree size and species composition.

Of the 19 original stands, 10 received moderate to heavy gypsy moth defoliation two or more times during the intervening 20 years. There were 22 1/10-acre plots distributed among the 10 stands. While detailed defoliation history (by tree) for the first 10 years (1970-1979) exists, the last 10 years are based on the sketch-map defoliation surveys. The defoliation (moderate to heavy) histories among the 10 stands ranges from a low of twice in the 20 years in three stands to a high of seven in three stands (Table 1). The average for all stands combined is one moderate or heavy defoliation per 4.3 years. In actuality, the defoliations were primarily clustered around two epidemics (1971-1973 and 1981-1982). Calculations were made on the changes in species composition based on stems per acre and basal area during the 20-year period (1970-1990). Mean diameter was also calculated for each stand.

There is not enough data from the 10 stands to make the results statistically meaningful such that they could be extrapolated to larger areas. Rather, one should view this information as simply a "snapshot" view of 10 stands with various gypsy moth defoliation histories at two (or three) points in time.

Results

The average oak mortality during the first 10 years (1970-1979) was: after one year of heavy defoliation--18 percent, after two years of heavy defoliation--89

Table 1. Gypsy moth defoliation history in ten "permanent" plots - 1970-1990.

Plot and County	Severity and Year of Defoliation*
Shartlesville Berks County	H(72), M(81)
Saylorsburg Monroe County	H(71), M(73), H(81)
Bethlehem Reservoir Carbon County	H(73), H(82)
Matamoras Pike County	H(81), H(82)
Strauss Lake Lebanon County	H(73), H(74), M(81), H(82), H(83)
Kunkletown Monroe County	M(69), H(70), H(71), M(72), M(73), M(80), H(81)
Ressica Falls Monroe County	H(71), H(72), H(73), M(76), M(77), M(78), M(81)
Woodpecker Lake Pike County	M(70), H(73), M(77), H(81), M(82)
Shohola Pike County	H(71), H(72), H(73), M(77), H(81), H(82)
Aaronsburg Centre County	H(69), H(73), H(74), M(76), H(77), H(82), H(89)

*1970-1979 is based on tree-by-tree observation. 1980-1990 is based on aerial sketchmaps of defoliation. M = moderate (31-60 percent), H = heavy (60+ percent) defoliation.

percent, after three years of heavy defoliation--98 percent. The combined species mortality in the stands ranged from 14 percent for one year of defoliation, 38 percent for two years of defoliation, and 48 percent for three years of defoliation. Four of 23 plots sustained 100 percent oak mortality after two or three heavy defoliations. The oak composition among the four stands ranged from 22 to 78 percent in 1970. The changes that took place in the four stands that received only two or three moderate to heavy defoliations during the 20 years are unsurprisingly small. The species composition changed very little. There was some tree attrition, but that is normal in any stand as it matures.

The six stands that received five to seven gypsy moth defoliations (Strauss Lake, Kunkletown, Ressica Falls, Woodpecker Lake, Shohola, and Aaronsburg) during the 20 year-interval showed noticeable changes in both species composition and mean diameter. As one would expect, the oak component was reduced in most of the plots. However, ingrowth more than offset the losses. The most noticeable were black birch and white ash in the Kunkletown plot and the white pine and hemlock in the Aaronsburg plot. Because of the shift in size classes, the mean DBH was reduced in most plots in spite of an overall slight increase in basal area.

The bottom line is similar for all these stands. They all have about the same basal area as they did 20 years ago, regardless of the number of defoliations or amount of oak mortality. The average basal area for all 10 stands increased from 109 square feet in 1970 to 126 square feet in 1990 (Table 2).

Discussion

The Kunkletown plot lost 90 percent of its oak and 84 percent of the sassafras, yet with the accretion on the residual surviving trees (primarily red maple and black gum) and the ingrowth (white ash and black gum) the stand was well stocked in 1990. In one respect, the stand is much improved from a pest management standpoint. That is, with less oak, it will be less attractive to gypsy moth, oak leafshredder, oak leafroller, and other oak defoliators. The same can be said for the Aaronsburg stand. Although the oak component is still high, the increased proportion of other species, like white pine and hemlock, will undoubtedly make the stand more gypsy moth resistant.

The Woodpecker Lake data shows an increase in chestnut oak in spite of the five defoliation events over the 20 years. The 1990 data was acquired from variable-radius plots and therefore was not taken in the exact location of the 1970 1/10-acre plots. Nevertheless, the results show that five gypsy moth epidemics there have not caused wholesale destruction of the forests or the oak component in that general area. Even more striking is the Ressica Falls site that showed very little change in all species including oak, despite seven defoliation events!

The stands at Strauss Lake and Shohola had five and six defoliations, respectively. While they both lost a considerable number of white oaks, they absorbed the losses rather well. The Strauss Lake stand did not have much ingrowth, but the accretion on surviving trees offset most of the losses. At Shohola, there was a lot more white pine and red maple in 1990. Admittedly, these data are insufficient to stand up to statistical scrutiny, particularly since there were variations in methods of acquisition. However, they are sufficient to demonstrate that the stands we tracked ameliorated the effects of repeated gypsy moth attack. The stands, on average, are as well stocked and healthy now as they were 20 years and multiple defoliations ago.

Summary

Despite the fact that the average basal area increased, the stands would all probably have measurably greater increases had not gypsy moth-caused stresses altered the course of events. Obviously, there would be considerably more oak trees. Also, the average tree diameter in the stands is probably smaller due to the replacement of large trees by more numerous saplings and small-pole trees.

There is one beneficial aspect to all of these changes in that the increased species diversity, particularly the addition of white pine, hemlock, and white ash, have rendered the stands less susceptible to future gypsy moth outbreaks. Further, the stands are looking quite healthy despite the considerable mortality that occurred in some stands. Overall, there is more basal area now than there was in 1970.

Table 2. Gypsy moth permanent plot summary - defoliation effects - all stands combined.

Species	Per-Acre Estimates				Mean Diameter	
	Number of Stems		Basal Area			
	1970	1990	1970	1990	1970	1990
White Pine	7	17	4.05	6.84	11.3	10.6
Hemlock	19	20	8.29	10.73	7.3	10.2
Pitch Pine	0	0	0	0.56	0	18.5
Red Maple	63	57	15.54	20.45	5.4	7.2
Red Oak	11	16	7.34	11.28	9.5	11.8
Black Oak	7	4	2.71	2.13	8.2	9.5
Scarlet Oak	33	10	5.24	3.24	5.3	8.2
White Oak	63	36	31.07	23.70	8.3	10.3
Chestnut Oak	31	26	16.30	17.24	9.4	9.9
Yellow Birch	0	5	0	1.11	0	5.5
Sweet Birch	14	21	4.07	8.87	7.0	8.4
Beech	8	13	6.06	8.77	10.0	8.6
White Ash	3	8	.55	1.27	5.7	6.8
Black Ash	1	1	.20	.25	6.0	6.8
Yellow Poplar	1	2	.44	1.39	9.0	11.2
Hickory	2	10	.24	3.84	5.5	8.0
Black Gum	9	7	4.73	3.62	9.6	9.7
Black Cherry	0	0	.03	0	4.2	0
Flowering Dogwood	0	0	.03	.02	3.7	3.8
Sassafras	10	2	2.19	.53	5.9	7.3
Miscellaneous	2	0	.18	0	4.3	0

Chestnut Ridge Revisited

This survey was conducted in a five-acre stand within a much larger contiguous forest on Chestnut Ridge near Kunkletown in Monroe County. Personnel from the Delaware Forest District office (District 19) surveyed this small tract in 1971 when they observed heavy tree mortality. This stand was defoliated to some degree (moderate to heavy) in 1969, 1970, 1971, 1972, 1973, and again in 1980 and 1981.

In 1971, the District estimated that one-fourth of the oak sawtimber and two-thirds of the oak pulpwood were dead. The remainder of the oak was in a state of decline. When the stand was revisited in 1972, the residual oaks were in such a condition that none were expected to survive.

While all of the red oak sawtimber disappeared from this stand, it is apparent that some of the "declining" chestnut oak sawtimber survived. There were 1,171 board feet/acre of "declining" chestnut oak in 1971 and 360 board feet/acre (including growth and ingrowth) in 1990. There was almost as much volume in pulpwood-size oak trees in 1990 (80 cubic feet/acre) as there was in "declining mixed oak" in 1971 (81 cubic feet/acre). Still, the reduction in oak component for this small stand was sizable--oak pulpwood, 51.5 percent of the stand in 1971, decreased to 9.1 percent in 1990; oak sawtimber, 82.7 percent of the stand in 1971, was only 3.1 percent in 1990. A number of other species have filled in during the intervening years. Red maple, black gum, scarlet oak, white ash, and sassafras sawtimber all were represented in 1990 but not 1971. In the adjacent stand, pitch pine, hemlock, and aspen sawtimber now make up nearly 30 percent of the net volume. Of particular interest is the relatively large volume of oak (180 cubic feet/acre and 720 board feet/acre) in 1990. It is not unusual to see differences in impact between stands with comparable defoliation histories. These differences may be attributable to a number of site factors rather than differences in defoliation intensity.

The total volume of merchantable wood in the five-acre stand increased during this period (up approximately 300 cubic feet per acre). Despite a 27 percent reduction in sawtimber volume (2,030 to 1,480 board feet/acre), the pulpwood volume nearly doubled (468 to 880 cubic feet/acre). Although the adjacent stand (1990) had more sawtimber, the overall wood volume was approximately 88 cubic feet less than the 1990 volume.

A lot of mortality? Surely. Catastrophic? Hardly. The stand on Chestnut Ridge has become more resistant to gypsy moth by virtue of the reduced oak component. That's certainly good. Undoubtedly, there is less total volume there than what would have been in the absence of the gypsy moth impact. Despite the negative trend in sawtimber, the average tree size doubled (2 to 4 cubic feet) during the 19-year interval, while the average number of trees per acre decreased by 44 percent. At worst, the stand lost a few years of growth. At best, local people got a lot of splendid oak firewood, and there is still a fully forested Chestnut Ridge.

Windshield Survey in Districts 3, 5, and 7

The third survey consisted of observations made during a tour in areas of Districts 3, 5, and 7 where gypsy moth epidemics occurred in the early to mid-1970's and large amounts of tree mortality followed. These observations are just that. No plots were taken; no measurements were made.

Overall, lots of healthy, well-stocked stands with lots of oak were seen. Also vast amounts of white pine and hemlock reproduction came up in all three Districts. The mortality that occurred in these areas has almost wholly been masked by the accretion on residual trees and ingrowth.

Nearly all of the heavy mortality in District 3 occurred in stands that had had some type of intermediate cut prior to (or subsequent to) the defoliation. Many of the stands were subsequently salvaged. Some were clearcut. Those that were treated with a shelterwood/salvage have since lost many of the residuals.

The primary concern with these salvage areas is the lack of "desirable" reproduction. Black birch and striped maple abound in several of these areas. Black locust, sassafras, and red maple are also common. Other species found in fewer numbers include chestnut oak, beech, red oak, and tulip poplar. Oak seedlings are plentiful in some areas; however, they are heavily browsed by deer. Problems with adequate oak reproduction are not restricted to these salvage areas. Quite a few compartments have a dearth of knee-high and waist-high oak seedlings and saplings. In fact, often a stand cannot be rotated for failure to meet the management guidelines for amount and quality of advance reproduction. Reasons for this vary, but certainly deer browsing plays a major role. Where fences have been erected to restrict the movement of deer, the problem of lack of regeneration is greatly alleviated.
Notwithstanding these problems, District 3 forests appear quite healthy and well stocked. Oak is the predominant species in most stands. White pine reproduction is common in many areas--especially on ridges.

The small portion of District 5 forests observed appear to be doing very well in spite of the heavy tree mortality that occurred. There are numerous dead trees still standing. However, residual trees appear to be quite healthy and growing well. That, along with ingrowth, will soon have most of the stands back to predefoliation stocking levels. Granted, the average tree size may be smaller than before, but the species mix is no doubt better from a pest manager's viewpoint (less oak). White pine and hemlock seedlings and saplings are abundant in numerous locations. If nothing detrimental happens to these conifers, there can be little doubt that the "next" forest will contain significant proportions of them.

The general impression of areas observed in District 7 was not unlike that in the other two Districts--lots of healthy-appearing trees, including oak with white pine coming in almost everywhere. The view from overlooks, roadsides, and Sand Mountain tower is one of well-stocked stands of mixed oak.

These observations are admittedly cursory. Regardless, the woods look good considering the number of trees that died. A lot of "healing" has occurred. Aside from the immediate loss of stumpage values, these forests are more diversified because of the changes. With less oak, there will be a decreased susceptibility to gypsy moth (and other insects like oak leafroller and oak

leafshredder). The species that are filling in the void may not now have the economic value of oak, but who knows what markets will open up when a new resource becomes available?

Summary

The real impact of timber mortality depends upon your perspective. If you happen to own a 50-acre parcel of forestland stocked to the hilt with prime, veneer-quality white oaks that all died, it's a sizable loss. Even if you salvage the trees, they cannot be sold as veneer logs. However, to a sawmill operator it could be a windfall of thousands of board feet of select logs acquired at a relatively low price. A park superintendent would be less likely to bemoan the death of some trees than would a tree farmer, particularly if the stand regained the lost stumpage in the subsequent five to ten years. Most park visitors probably do not recognize any difference between a stand of primarily oak and one comprised of red maple, black gum, and black birch. Another important consideration is that many of the trees that were killed because of gypsy moth defoliation would have died during the normal course of events anyway. Certainly, there were some dominant and codominant healthy trees that succumbed. However, most of the trees that died had been suppressed and unthrifty. A forest stand starts with 50,000 to 100,000 seedlings per acre and climaxes with 200 to 400 mature trees. Along the way a few thousand pass out of the picture. The gypsy moth simply hastens the process.

To the manager of a large tract of forestland, the loss of one-third of the basal area in a few stands tends to be less than catastrophic. Net growth in Pennsylvania is presently greater than removals (including inordinate tree mortality) by a factor of 2.2 to 1 (Powell and Considine 1982). Obviously, there's more wood growing than we're able to utilize. Again, that doesn't mean that no one is hurt by all this tree mortality. A good example is the select white oak category, the only species group that had removals exceeding growth during the last inventory period.

On the bright side, with fewer oaks in the residual stand and the large number of conifers coming in, the forests of Pennsylvania are becoming gradually but significantly less susceptible to gypsy moth attack. As time goes on, it is inevitable that oak will be less common while white pine, hemlock, and a number of hardwoods will fill in the voids. This diversification will be a net positive outcome for most forests.

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ASIAN GYPSY MOTHS ENTER NORTH CAROLINA BY WAY OF EUROPE: A TRIP REPORT

By Thomas H. Hofacker, Michael D. South and Manfred E. Mielke

EDITOR'S NOTE: Gypsy moth populations have reached outbreak proportions in parts of Germany, Switzerland, France, the Slovak Republic and northern Austria. Contaminated shipping from ports in these countries represents a serious source of gypsy moth introduction to North America. This happened in the Northwest last year, and in North Carolina this year. In Montreal, egg masses were intercepted on a ship arriving from Germany.

The outbreak of gypsy moth populations in Europe, coupled with hybridization between Asian and North American gypsy moths has set the stage for a whole new chapter in gypsy moth control. The Animal Plant Health Inspections Service (APHIS), and Agriculture Canada are working to strengthen their regulatory efforts. If you are at all interested in the regulatory aspects of pest management, this is one hot topic!

On July 4, 1993 a military cargo vessel carrying U.S. Army munitions from Nordenham, Germany, docked at the Sunny Point Military Ocean Terminal, near Wilmington, Brunswick County, North Carolina. On July 6, the deck hold of this ship were found to be contaminated with gypsy moth pupae, adults, and egg masses. One startling sight was that of "thousands" of FLYING female gypsy moths! Believing that these could be Asian gypsy moths or a European-Asian hybrid, cargo movement was stopped, the holds were closed, and the vessel was ordered to leave the port immediately. The ship was later fumigated. All other major ports have been alerted concerning this new pest risk. It is not known how many of these adults made it to shore, but pheromone traps placed in the vicinity have already caught male gypsy moths at distances of 8-10 miles from the port. A large-scale eradication program is now being contemplated for the Wilmington area.

Inspectors captured 27 adult moths on the ship. These specimens were set to the USDA Forest Service laboratory at Delaware, Ohio, where they determined the origin of various gypsy moth strains, using nuclear DNA. This technique demonstrated that of the 27 moths collected, 2 males were the Asian strain, 3 males and 12 females were the European strain, and 1 male and 9 females were Asian x European hybrids.

One major difference between these strains is that females of the European gypsy moth strain CANNOT fly, while females of the Asian strain CAN fly.

Apparently, Asian gypsy moths entered western Europe sometime in the recent past, and they are hybridizing with the local European strain. In response to this find, a team comprised of the authors was formed to visit Germany to assess the situation there.

We left the United States on July 21 and arrived in Frankfurt, Germany, on July 22. We then traveled to Freiburg and contacted Dr. Hermann Bogenschutz to discuss the gypsy moth situation in southern and central Germany. Dr. Bogenschutz said that the last major gypsy moth outbreak in Germany occurred about 50 years ago, but that there was a small epidemic in 1984-1986. Dr. Bogenschutz saw two flying gypsy moth females for the first time in 1992. This year, the outbreak in Germany was larger than anticipated. There were many flying females reported with some villages turning off their street lights at night to reduce the number of moths flying into town. The females apparently fly at night. Some small forest areas were sprayed with Dimilin on an experimental basis and some infested vineyards adjacent to infested forests were sprayed as a preventative measure with parathion under an emergency permit.

On July 23, we were given several locations in Germany where flying gypsy moth females had been seen. In addition to Germany, Dr. Bogenschutz told us that he was aware of recent reports of gypsy moth epidemics in France, Switzerland, the Slovak Republic, and in Russia. In the afternoon,

we visited a defoliation site in the Black Forest west of Freiburg. We found several females and some egg masses, but saw no flying females at this site.

On July 24, we left for Heidelberg, stopping at several sites to collect adult moths and egg masses. At one stop, about 30 kilometers south of Heidelberg, we found many females laying eggs on the sides of buildings. We were able to get 3 females to fly.

On July 26, we met Dale Rush, an APHIS International Services officer stationed in Germany. He had set up a meeting with the U.S. Army unit in charge of shipping U.S. munitions, household goods, vehicles, and other items within Europe. This meeting focused on possible changes in APHIS inspection policy for articles returning to the United States. For example, preclearance and inspection policies may need to be improved.

The entire U.S. Army Base near Heidelberg was contaminated with gypsy moth egg masses. We learned that containers bound for Germany's northern port cities may sit for 2-4 weeks before being moved out. Following the meeting, many of us traveled to Lorsch, the site from which the contaminated containers that arrived in North Carolina were shipped.

At Lorsch, egg masses covered the trees and buildings. One guard said he had removed more than 10,000 egg masses from inside a guard tower. Only three containers remained at the Lorsch site, and all three were contaminated with egg masses. Ammunition bunkers had female gypsy moths and egg masses. We learned that the containers that had been shipped to North Carolina had been stored adjacent to and underneath infested trees on this site. All oaks at the site had been defoliated.

The Lorsch site is scheduled to be returned to the German government in the near future. Before leaving Lorsch, we recommended that they burn the dunnage piles (i.e., wood and logs used to support or brace cargo). The normal practice was to sell or give the dunnage away to the local populace to be used as firewood.

On July 28, we met Lt. Col. Kavey at Bremerhaven, where he stated that his group handles all shipment of ordinance, household goods, and vehicles from Germany to the United States. We inspected warehouses in Bremerhaven and Nordenham, but found no gypsy moth life stages. We recommended that pheromone traps be deployed at these ports, in the surrounding area, and along nearby railroads where ordinance trains wait for ships. In addition, we were told that some of the humanitarian aid to Russia will return to these ports. Lt. Col. Kavey said that inspections at Bremerhaven/Nordenham would be impossible because of downsizing.

On July 29, we traveled from Bremen to Frankfurt, making various stops along the way. On July 30, we returned to the United States, cleared customs, and then shipped the gypsy moth adults and egg masses we had collected to APHIS.

Based on our observations, we reached the following conclusions:

1. There is a large gypsy moth outbreak building in central Germany.

2. There are many female gypsy moths in central Germany that can fly.

3. Flying female gypsy moths appear to be capable of flying long distances. This was very difficult to assess, but many towns where we saw females and egg masses on buildings were not near any outbreak. Flight capability of 3 to 5 kilometers or more appears likely.

4. The presence of a large number of flying female gypsy moths at the time when there is a major pullback of U.S. troops and equipment from Germany presents a significant threat of introduction of flying females into the United States.

5. It is virtually certain that the contaminated containers that arrived in North Carolina became contaminated at the munition storage area at Lorsch.

Based on our observations, we make the following recommendations:

1. Immediately send gypsy moth identification information to military entomologists and military customs inspectors (MCIs) in Germany.

2. Increase vigilance in the U.S. and Germany. Consider inspecting in both the U.S. and in Germany.

3. Provide training to MCIs on inspection techniques for returning outdoor household articles and vehicles.

4. Consider the need for survey and treatment of infested military staging, storage, and housing sites to reduce the risk of returning articles being infested.

5. Contact uniformed services other than the Army to inform them of the potential problem.

6. Assess the hazards in countries other than Germany such as Austria and France.

7. Convene a meeting of military, APHIS, Forest Service, and German Federal and State personnel to plan strategies for 1994. Our observations indicate that there is a very extensive gypsy moth outbreak developing in central Germany and that the situation will likely be much worse in 1994.

8. Based on the potential for having larvae and pupae disseminated en route from Lorsch to the ports of Bremerhaven and Nordenham, pheromone traps should be deployed in and around the ports and at the NATO troop training area near Bergen-Hohne.

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ARKANSAS REVISITED!

By Bobbe Fitzgibbon

The gypsy moth infestation near Compton, Arkansas, is more widespread than was previously thought. Delimiting trapping in 1993 indicates that the moth is established in a much larger area than was treated in May. Trap catches are numerous in a 34 square mile area surrounding the 1993 treatment block and a multiple catch has been made as far as 12 miles north of the block. Six multiple catches were made on the Buffalo National River and several moths were collected within the Ponca Wilderness. A meeting is being held in Little Rock on September 21st and 22nd to determine what strategies will be used to eradicate this isolated population. While the project will be a cooperative effort between the Arkansas State Plant Board and the USDA Forest Service, many agencies will have a role in the effort. Representatives from APHIS PPQ, the Buffalo National River, the Arkansas State Forestry Commission, Arkansas Game and Fish Commission, and the Missouri Department of Agriculture will also be involved in the meeting.

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Egg Mass Sampling for Decision-Making

By Andrew Liebhold, Kevin Thorpe, John Ghent, and Barry Lyons

A key element of any forest pest management program is the careful evaluation of a forest area to determine gypsy moth population levels. The two most commonly used measures of gypsy moth density are counts of males in pheromone traps and counts of over-wintering egg masses. Pheromone traps are mostly used in isolated populations outside of the generally infested area and in areas along the expanding front of the gypsy moth infestation. In these areas, pheromone traps are useful for detecting and delineating new infestations and for identifying rising populations that warrant more intensive surveys. Within the generally infested area, management programs designed to suppress populations or prevent defoliation, rely on counts of over-wintering egg mass populations to make decisions about control options. The availability of egg masses from late summer through spring provides ample time for censusng population levels while still leaving adequate opportunity for treatment planning. Furthermore, gypsy moth egg masses are probably the most convenient stage to sample because most are visible from the ground.

The objective of most gypsy moth egg mass sampling procedures is to estimate egg mass density, expressed as numbers per unit ground area (usually number per acre). Expression of densities as numbers per tree is less desirable because the number and size of trees per acre varies and egg masses are often not located on trees. Density estimates can be used to predict defoliation levels using one of several previously developed density-defoliation relationships (see page 20). Most management programs simplify matters by establishing density thresholds for invoking intervention; these egg mass density thresholds correspond to impact thresholds, above which defoliation and other impacts are considered intolerable.

Probably the simplest method of measuring egg mass densities is with the use of "fixed-radius" plots. All of the egg masses within a circle (usually covering 1/40th acre) are counted. Several of these plots are used throughout the stand in order to estimate density. This technique has the advantage of simplicity: density is the average density from all plots.

Fixed-Radius Plot Method - Procedures

Survey area. The first step in conducting a gypsy moth egg mass survey is to determine the boundaries of the management unit over which to estimate egg mass density. This may be simple as in the case of an isolated, uniform oak woodlot. It may be more complicated in areas that are not continuously wooded or in wooded areas in which the density of oaks is not uniform. In the latter situation, it may be advisable to break the total area up into smaller areas for the purposes of estimating egg mass density. The management unit boundaries should be located such that each unit is relatively homogenous both in terms of management objectives and in terms of forest composition. Management units typically range from 10 to 500 acres; any area larger than 500 acres usually is so heterogeneous that it should be subdivided. Some management areas may not require sampling as defoliation may not conflict with management objectives.

Number of Samples. Gypsy moth egg masses are typically irregularly distributed within an area. For example, large gnarly oak trees tend to accumulate large numbers of egg masses. Plots containing one of these so called 'wolf ' trees would provide a much higher density estimate than would an adjacent plot without such a tree. It is this type of situation that causes the variation between plots and creates the need to sample using several plots per stand.

The number of sample plots that are necessary is determined by the expected variation among samples and by the maximum estimation

error that is acceptable. This error is often expressed as a proportion of the estimated density. The maximum estimation error depends upon the constraints of the management program and the density one is estimating. For example let us consider an estimation error of 50 percent; if the estimated density is 4,000 egg masses per acre, the manager may not care whether the actual density is 2,000 or 6,000 egg masses per acre. But if the estimated density is 400 egg masses per acre, the decision whether to treat may be highly dependent on whether the actual density is 200 or 600 egg masses per acre. In this case an estimation error of 50 percent would be unacceptable.

The required number of samples is also dependent upon the expected variation among samples. Typically, the variation among samples is strongly related to population density: variation is greatest at high densities. For this reason we are able to provide a minimum number of samples required for a variety of population densities. Figure 1 depicts curves which give these values for a variety of maximum errors. To use these curves requires two pieces of information: 1) the maximum allowable error and 2) an estimate of density. When using this graph the estimate of density can be a very approximate value obtained from a superficial examination of the stand.

If an error of 25 percent is considered acceptable, and the population density is expected to be greater than 2000 egg masses per acre, then 15 samples are probably adequate. However, nearly 100 samples are needed to achieve a 10 percent error rate at the same population density. Under low (< 500 egg masses per acre) density conditions, up to 33 samples are needed to maintain a 25 percent error rate, and over 200 sample are required for a 10 percent error rate.

Location of survey points. Sampling theory tells us that samples should be placed randomly throughout the management unit. However, it is usually simpler, and still acceptable, to space the survey plots evenly. An easy way to do this is to draw a grid of lines on a map of the management unit as a guide for drawing the locations of the desired number of survey points (Figure 2). The grid points can be located by starting at some easily located landmark (e.g., a road) and pacing out distances between sample locations while following a fixed compass direction.

The exact location of the center of the survey plot is of critical importance, as it can greatly influence the number of egg masses that will be counted in that plot. Gypsy moth egg masses have a highly clumped distribution, which means that two side-by-side survey plots can contain vastly different numbers of egg masses. Since it is possible to learn to recognize those locations which will tend to contain the most egg masses, it is also possible to deliberately place survey points in these locations (or to deliberately avoid these locations). Either way, the estimated egg mass density for the management unit will not be accurate if such deliberate adjustments are made. In statistical terms, this is known as "bias". Deliberately locating survey plots in areas where egg masses are clumped would bias the estimates upward, resulting in an overestimate of the true egg mass density for the management unit. Deliberately locating plots away from clumps would bias the estimates downward, resulting in an underestimated egg mass density. To prevent this kind of bias, egg mass survey plot locations should be selected as if the sampler had no knowledge of egg mass distribution.

Plot layout. Either a circle or a square plot may be used, depending on the preferences of the sampler. It is relatively easy to

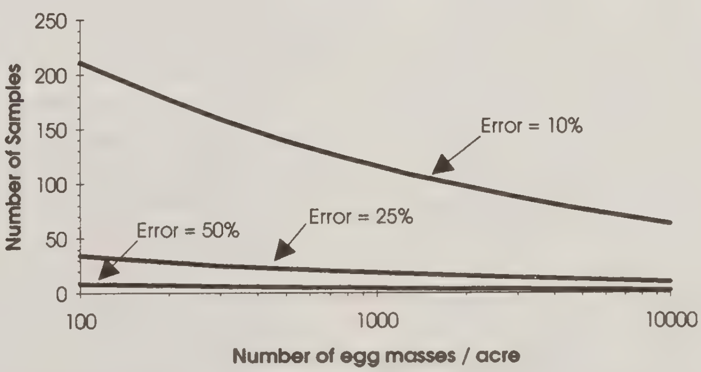

Fig.1. Minimum number of fixed radius samples (plots) necessary to achieve various levels of precision at different densities. Error is expressed as a percentage of estimated density.

easure the perimeter of a circle by anchoring one end of a piece of rope cut to a length of 18.6 feet (the radius of a 1/40th acre circle) and pulling the other end out to mark the perimeter.

Counting egg masses. The next step is to attempt to count all of the egg masses present within the boundary of the survey plot. First, count all egg masses located on trees that fall within the perimeter of the plot. Binoculars must be used to see into the canopy. It will be necessary to examine each tree from different vantage points so that all sides of it can be seen. Small to medium trees will usually require exami- nation from two opposed vantage points. Large trees may require examination from more than two vantage points. Care should be taken to avoid counting the same egg mass more than once. This can be accomplished by scanning the trunk and branches systematically with the binoculars. All objects on the ground, such as logs and rocks, should be examined for egg masses. This may involve moving these objects so that all surfaces can be seen. Weather conditions influence both the accuracy and speed of counting egg masses. Try to count egg masses under good weather conditions, which are when the sky is clear and the sun overhead. It is virtually impossible to count egg masses on objects on the ground in the presence of a snow cover. Recent studies have shown that counts are more accurate after trees have dropped their leaves in the fall. However, in operational programs it is often not possible to wait that long to begin collecting egg mass count data.

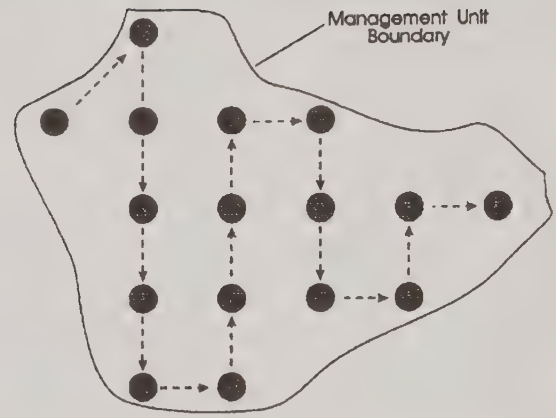

Fig. 2. Arrangement of fixed-radius plots within a hypothetical management unit (routes for walking between plots are shown as dashed lines.

Old vs. new egg masses. Egg masses that have recently been deposited usually differ in appearance from old egg masses that remain from previous seasons. New egg masses are usually darker in color and appear less ragged (Table 1). It is generally not recommended to attempt to distinguish new and old egg masses visually. Therefore when making counts in the crown, count all egg masses, regardless of whether they appear old or new, and even if they are partially missing. A much more reliable determination of whether an egg mass is new or old can be made by touching it. New egg masses feel hard and full, while old egg masses feel soft and spongy. Of course, only egg masses within reach can be examined in this way. Therefore, examine by touch all egg masses that are within reach from the ground and determine the proportion of those egg masses that are new. This proportion can then be applied to adjust the number of egg masses counted in the crown. Because some survey plots may not have many egg masses available at ground level, data from all of the survey plots within a stand should be pooled together for the purposes of calculating the proportion of new egg masses. See Table 2 for an example of these computations.

Table 1. Characteristics useful for differentiating new vs. old egg masses.

Old Egg Masses	New Egg Masses
soft to touch	firm to touch
dull or bleached coloration	darker beige
exit holes present	may contain parasitoid exit holes

Table 2. Sample calculation of egg mass density.

------------------ Egg Mass Counts ---------------------					
	Objects on Ground		Tree Stems		Crown
Plot	Old	New	Old	New	
1	0	2	2	5	2
2	1	1	5	2	0
3	3	0	0	7	6
4	0	1	3	1	4
5	1	3	7	6	14
6	0	0	1	0	3
7	0	0	0	1	2
Total	5	7	18	22	31

Total New = ground_{new} + stem_{new}
= 7 + 22
= 29

Total Old = ground_{old} + stems_{new}
= 5 + 18
= 23

Proportion New = Total New ÷ (Total New + Total Old)
= 29 ÷ (29 + 23)
= 0.56

Density = 40 x (Total New + Proportion New x crown) ÷ Number of Plots
= 40 x (29 + 0.56 x 31) ÷ 7
= 183 egg masses per acre

Estimating egg mass density. Since the survey plots are 1/40th of an acre in area, the number of egg masses per acre at each survey plot is estimated by multiplying the estimated eggs per plot by 40 as illustrated at the bottom of Table 2. The egg mass density estimated following the procedures in Table 2 represents an average for all of the plots. It is important to also calculate the standard error of the estimated mean egg mass density, which can be used to determine how much confidence can be placed in the estimate. Means and standard errors can be calculated on some hand calculators, but it is best to enter the estimated egg mass density for each survey plot into a computer spreadsheet and request that means and standard errors be calculated. A useful way to establish the level of confidence that you can place in the estimated mean is to calculate confidence intervals, which indicate the probable range of values for the true mean. For example, the 80 percent confidence interval is the range of values within which one can be 80 percent certain that the true mean occurs. The following formula is used to calculate an 80 percent confidence interval:

$$CI = \text{mean} \pm 1.6 \text{x} SE$$

Interpretation of survey results. There is no magic formula for interpreting the results of an egg mass survey. If the treatment threshold (the estimated egg mass density at which treatment should occur) is above the upper limit of the 80 percent confidence interval, then you can be 80 percent certain that the threshold has not been exceeded. Conversely, if the threshold is below the lower limit of the 80 percent confidence interval, then you can be 80 percent certain that the threshold has been exceeded. If the threshold falls within the 80 percent confidence interval, then it is likely that egg mass densities are near the threshold. However, the ultimate decision of what management actions should be taken must be made after consideration of available funds and manpower, sensitivity of host resources, and likely consequences of defoliation.

Prediction of Defoliation from Measurements

Pretreatment egg mass density is related to subsequent defoliation (Figure 3).

The points on the graph represent data from stands where egg mass density and defoliation were measured. The solid line is a statistically developed relationship.

This line can be used for predicting defoliation by simply locating the estimated egg mass density and then moving up vertically to hit the line, then follow over to the left to read the predicted defoliation level. One thing that is obvious from the wide scatter of observed points about this line is that there is a great deal of uncertainty in the relationship. Part of this uncertainty is due to measurement error in estimating density and defoliation but the other uncertainty component is that the underlying relationship between "true" egg mass density and "true" defoliation is variable. This uncertainty is important to consider when making management decisions. The problem is particularly acute when densities range from 100 to 1000 egg masses per acre where defoliation may vary between 0 and 100 percent, regardless of estimated density. In these situations, the manager must realize that any prediction is quite likely not going to be correct and other factors (such as egg mass size) should be considered.

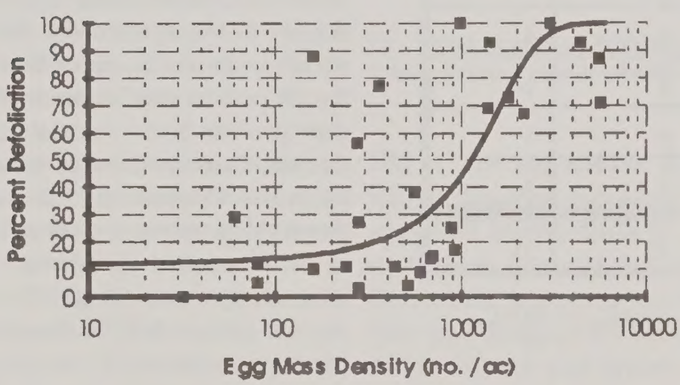

Fig.3. Relationship between egg mass density and defoliation at several locations.

Another factor that might enter into the decision making process at this point would be the regional conditions. If we have identified a low to moderate density population in a stand, the presence of high density populations in surrounding areas probably will increase the probability of defoliation occurring. Similarly, a moderate to high density population surrounded by low density or declining populations is probably less likely to cause defoliation. Therefore, the prudent manager should consider population levels and trends in the region surrounding the area of interest and integrate this information in decision-making.

Management Thresholds

Before conducting an egg mass survey, land managers should have clearly defined management objectives. These objectives will help in determining areas for survey, the intensity of the survey, and guidelines for establishing treatment thresholds. For most gypsy moth programs the management objectives are either nuisance abatement, preventing defoliation, and indirectly preventing tree mortality or a combination of these objectives. Each of these objectives should have their own intervention threshold.

Information on the impacts associated with defoliation will aid the manager in establishing thresholds. These thresholds will help determine when and where treatments are needed. In a forest, about 30 percent of the leaves must be eaten for defoliation to become noticeable from the air. Studies have shown that growth loss begins at 40 percent defoliation, and is proportional to the percent of defoliation thereafter. Refoliation occurs when about 60 percent of the foliage is lost. Refoliation results in the loss of a tree's stored reserves, which in turn is directly related to growth loss and the trees overall health and survival.

The levels of gypsy moth density in residential and recreational settings at which concern or nuisance occurs have not been established. For some individuals the sight of a few larvae may be intolerable, while others may not be concerned until defoliation is evident. Unsuspecting individuals may not even notice non-defoliating populations.

Selection of thresholds by management objectives is demonstrated in Figure 4. This figure shows what egg mass densities predict various levels of defoliation in a forested area. For the prevention of noticeable defoliation (>30 percent defoliation) an intervention threshold value of 500 to 750 egg masses per acre might be

appropriate. To prevent growth loss (>40 percent defoliation) then 700 to 900 egg masses per acre could be set as a threshold. Finally, to prevent mortality (>60 percent defoliation) a threshold of 1000 to 1400 could be used. The manager may chose to modify these to lower levels if the stand has been subjected to other stresses that may predispose trees to mortality or the stand's stocking or basal area is low. Experience in survey and knowledge of local forest condition will help establish threshold values that meet your management objectives.

An intervention threshold value of 250 egg masses per acre has been widely used in the past for intervention in both general forest and residential areas. While this value may be justified for reducing certain nuisance impacts, it may not be justified for other management objectives. If amanager's objective is to prevent noticeable defoliation, growth loss, or mortality, then initiating treatment at 250 egg masses per acre would show little or no return on the expense of treatment. Of course, Figure 3 illustrates that there is considerable uncertainty about the relationship between egg mass density and defoliation. Therefore, the significance of defoliation risk to management objectives should be a consideration when establishing intervention thresholds. While selection of an intervention threshold of 250 egg masses per acre may result in the needless treatment of many stands that would never become defoliated, it does reduce the risk of 30 percent defoliation.

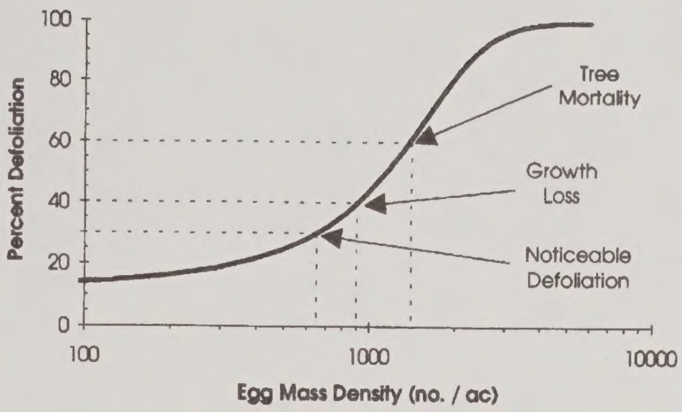

Fig. 4. Relationship between defoliation and egg mass density thresholds for three damage criteria.

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